Agriculture, Ecosystems and Environment 212 (2015) 187–197

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Agroecological, climatic, land elevation and socio-economic determinants of pesticide use at the farm level in Bangladesh

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ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form 10 May 2015
Accepted 5 July 2015
Available online 25 July 2015

Keywords:
Pesticide use
Multivariate Tobit analysis
Agroecology
Climate
Land elevation
Bangladesh

ABSTRACT

This study examines the influence of agroecology, climate, land elevation and socio-economic factors on pesticide use at the farm level using a large survey data of 2083 farms from 17 districts covering 10 agroecological zones in Bangladesh by applying a Tobit model. Overall, 75.4% of farmers used pesticides in any one crop. Within the pesticide users, pesticide use rate is highest in oilseed production estimated at BDT 2508.6 ha^{-1} (3.74% of gross output value) followed by jute at BDT 1976.1 ha^{-1} (1.88% of gross output value). Pesticide use is significantly lower in floodplain agroecologies, high rainfall areas, high land and low land elevation zones but significantly higher in medium high land elevation zone. Among the socio-economic factors, pulse area significantly reduces pesticide use whereas an increase in rice and pulse prices and organic manure application significantly increases it. Educated farmers and medium/large as well as small farms use significantly more pesticides. Policy implications include investments in developing crop varieties suitable for floodplain agroecologies, high rainfall, high land and low land elevation zones, expansion of pulse area and a reduction in fertilizer prices.

1. Introduction

Although pesticide application is supposed to be a damage control measure in preventing production loss from pest and/or disease attacks and is not a yield enhancing input, there is a widespread acceptance that the expansion of modern agricultural technologies has led to a sharp increase in pesticide use (Rahman, 2003a, 2013; Pingali and Rola, 1995). Pesticide is also believed to improve nutritional value of food and its use is viewed as an economic, labor-saving and efficient tool for pest management (Damalas and Eleftherohorinos, 2011). Furthermore, pesticide is believed to bring about competitive advantage for agricultural crops (Delcour et al., 2015). Pesticide use is growing continuously worldwide both in numbers and quantities since the 1940s. The total pesticide production has increased from one million metric ton (mmt) in 1965 to nearly 6 mmt in 2005 (Carvalho, 2006) despite widespread claim of its adverse effects, e.g., emergence of pest resistance and harm to human health and the environment (Hou and Wu, 2010; Pimentel, 2005; Pingali, 1995; Antle and Pingali, 1994). This is because pesticide use is seen as a necessity to retain the current production and yield levels and maintain high quality and standard of life (Delcour et al., 2015). It is predicted that pesticide use by farmers in developing countries will continue mainly due to (a) an ignorance of the sustainability of pesticide use; (b) a lack of alternatives to pesticides; (c) an underestimation of the cost of pesticide use both in the short- and the long-run; and (d) the weak enforcement of laws and regulations governing pesticide use (Wilson and Tisdell, 2001). Furthermore, pesticide efficiency and use can also be influenced by environmental conditions. It is expected that with climate change, pesticide use will also be affected leading to more pesticide application by farmers due to increased vulnerability to pests and diseases as well as reduction in pest residues in crops (Delcour et al., 2015).

Bangladesh is a country most vulnerable to climate change and, therefore, is susceptible to the range of effects outlined above including vulnerability to pests and diseases. This is because most food crops are sensitive to direct effects of high temperature and extreme precipitation as well as indirect effects of climate on soil properties, nutrients and pest organisms (Rosenzweig et al., 2001). Pesticide use in Bangladesh, negligible until the 1970s, has recorded a dramatic rise over the past few decades. For example,

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http://dx.doi.org/10.1016/j.agee.2015.07.002

pesticide use was only 0.26 kg of active ingredients per ha in 1977 but increased to 1.23 kg in 2002 (Rahman, 2010). In fact, pesticide use grew at an alarming rate of 10.0% per year during the period 1977–2009 although the corresponding response in yield growth of major crops has been minimal (<1.0% per year). As a result, pesticide productivity (i.e., 'gross value added from crops at constant prices' per 'kg of active ingredients of all pesticides used') is declining steadily at a rate of −8.6% per year during 1977–2009 (Rahman, 2013).

A limited number of studies are available which examined socio-economic determinants of pesticide use at the farm level in Bangladesh (e.g., Dasgupta et al., 2005; Mahmoud and Shively, 2004; Rahman, 2003a; Rahman and Hossain, 2003; Hossain et al., 1999). Although these studies provide valuable information on socio-economic factors influencing pesticide use, none of them considered the influence of the production environment and climate within which farming operations occur when identifying the determinants of pesticide use. This is because farmers' production performance does not only depend on the physical resources and technology available to them, but also on the existing environmental production conditions (Rahman and Hasan, 2008). In fact, pesticide efficiency, crop characteristics, pest occurrence and severity are directly influenced by climate (Delcour et al., 2015), and therefore, likely to influence pesticide use. Sherlund et al. (2002) and Rahman and Hasan (2008) noted that ignoring variables representing environmental production conditions in the models leads to biased parameter estimates. Both studies demonstrated that taking account of environmental production conditions significantly improved farmers' technical efficiency of input pesticide use for rice in Cote d'Ivoire (Sherlund et al., 2002) and wheat in Bangladesh (Rahman and Hasan, 2008). Specifically, pest infestation was found to be significantly positively correlated to area cultivated, mechanical power services, irrigation, herbicide use and organic manure (Rahman and Hasan, 2008) and child labor and fertilizers (Sherlund et al., 2002).

Given this backdrop, the present study examines the influence of agroecology, climate, land elevation, and a range of price and socio-economic factors on pesticide use at the farm level in Bangladesh using a recently conducted large survey data of 2083 farm households from 17 districts (or 20 sub-districts) of Bangladesh spread over 10 agroecological zones (AEZs). Our specific contribution to the existing literature is that we have incorporated a wide range of variables representing the production environment and climate within which farming operations occur as explanatory factors of pesticide use at the farm level which is previously non-existent. Incorporation of these variables will not only establish their direction and magnitude of influence on pesticide use but also provide a more accurate and unbiased estimates of all the parameters of the model as noted by Rahman and Hasan (2008) and Sherlund et al. (2002).

The paper is organized as follows. Section 2 presents description of the study areas, the data, analytical framework and the empirical model. Section 3 presents the results. Section 4 provides conclusions and draws policy implications.

2. Methodology

2.1. The study areas and the data

Bangladesh has a total of 64 districts and 486 sub-districts (BBS, 2013). Data for this study was taken from a recently completed NFPCSP–FAO Phase II project (Kazal et al., 2013). The data were collected during February–May 2012 through an extensive farm-survey in 17 districts covering 20 sub-districts (*upazillas*) of Bangladesh. A multistage sampling technique with mixture of purposive and stratified random sampling methods was employed. At the first stage, districts where the specified crops are dominant are selected purposively. The selection of the districts also took into account specified characteristics, i.e., land elevation types of the region and type of technology. At the second stage, sub-districts were selected according to highest concentration of these specified crops in terms of area cultivated based on information from the district offices of the Directorate of Agricultural Extension (DAE). At the third stage, unions were selected using same criteria at the union/block level which was obtained from the sub-district offices of the DAE. Finally, the

Table 1
Distribution of sample according to farm type by districts.

District	Sub-district	Farm type			
		Marginal	Small	Medium/large	Total surveyed farms
Tangail	Mirzapur	35	35	35	105
Mymensingh	Phulpur	34	36	35	105
Kishoreganj	Karimganj	35	35	35	105
Netrokona	Khaliajuri	21	38	46	105
Faridpur	Bhanga	35	35	35	105
	Boalmari	20	20	20	60
Rajshahi	Charghat	35	35	35	105
Natore	Lalpur	34	35	36	105
Sirajganj	Ullapara	35	35	35	105
Bogra	Sherpur	31	34	33	98
	Sariakandi	35	35	35	105
Jaipurhat	Kalai	35	35	35	105
Dinajpur	Chirirbander	36	30	39	105
	Birganj	70	35	35	140
Thakurgaon	Balia Dangi	35	35	35	105
Lalmonirhat	Hatibandha	34	34	37	105
Barisal	Bakerganj	35	35	35	105
Kushtia	Sader	35	35	35	105
Sunamganj	Derai	35	35	35	105
Habiganj	Baniachang	31	38	36	105
	Total	696	685	702	2083